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APOLLO PROGRAM OFFICE HEADQUARTERS

APOLLO
TEST MATURITY ANALYSIS REPORT
FLIGHT SA-6 (U)

15 FEBRUARY 1964

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TEST MATURITY ANALYSIS REPORT

SATURN I, FLIGHT SA-6/BP-13

15 FEBRUARY 1964

Prepared for

NASA

By

Apollo Program Support Operation
Test and Operations

Apollo Support Department
General Electric Company
Daytona Beach, Florida

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TEST MATURITY ANALYSIS REPORT

SATURN I, FLIGHT SA-6/BP-13

15 FEBRUARY 1964

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APOLLO PROGRAM OFFICE HEADQUARTERS

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SECTION I

1.0 INTRODUCTION

This report is the first in a series as specified in Contract NASw-410 concerning Apollo Test Maturity Analysis for specific flight tests of the Apollo Program. This issue, and succeeding periodic issues, is intended to fulfill the Test Maturity Analysis reporting requirements of the NASA/General Electric statement of work, dated 1 November 1963, paragraph A.3.2.4.9, which states in part:

> The contractor shall, based on analyses of the test program documentation and test program activities, compile and maintain qualification test status, and provide test maturity analyses.
>
> These test maturity analyses shall contain updated, detailed status data and analyses oriented to show impact on accomplishment of specific flight objectives.

It is intended in these test maturity analyses that the total test program be reviewed, the maturity of the total program be determined, and the effect of this maturity on specific flight tests be defined. This report presents the first attempt at a test maturity analysis and will start to determine the effect of the test maturity on the next Saturn flight, that is SA-6. This report will be oriented towards impact on the Saturn flight SA-6 with special emphasis on the effect of the test maturity on its flight test objectives and its flight hardware.

Thus, it is intended that this report and subsequent reports in the series give the Apollo Program Office Headquarters (APOH) management a timely analysis of test maturity of the Apollo Program and a determination of its effect on the flight test under analysis. It is planned that these reports will be issued 30 days prior to each Saturn launch.

Since this type of report will present a very current analysis of the total Apollo Test Program, with determination of its effect on a flight at hand, it will be most useful to management to determine whether the flight should progress as scheduled or whether certain alterations, redirections or reschedulings are required to obtain optimum information and assurance of success for that specific flight. Thus, it is intended that this type of report will be concise and the backup data or information on which the analyses are based will be located and referenced in the periodic Apollo Qualification Test Summary reports and their periodic supplements. However, in any critical areas uncovered in the test program, sufficient detail will be given to allow management to arrive at logical conclusions.

It should be emphasized at this point that the analyses presented in this report are based on a very small amount of the detailed test information. The information utilized was derived from available test and program schedules, logic diagrams, and general test plans. A complete bibliography of documentation, with dates is contained in Section VII. Specific test plans for the boilerplates and airframes used in the development and qualification programs leading up to flight SA-6 were not available at the time of this analysis. Also the required detailed information relative to the configuration of Boilerplate 13, the assigned payload for Saturn SA-6, trajectory information, mission descriptions, and detailed flight objectives were not available.

While it is realized that this report is based on minimal information it is deemed desirable to issue such a report at this time since it is the first in a series of new reports.

Thus, while it might seem logical to slip the proposed milestone approximately two months because of the slippage in the flight schedules, it is thought that more will be gained by issuing the report at this time, no matter how unsophisticated it may be, so that APOH can make some evaluation of the methodology, organization, utilization, etc. prior to the first complete analysis which is planned for April 15, 1964. The second analysis will also be oriented towards Saturn flight SA-6. It is hoped that at this later date, the required detailed information will be available so that a complete and thorough test maturity analysis can be made.

SECTION II

2.0 MISSION OBJECTIVES

The Saturn SA-6 spacecraft represents the first flight test of the Apollo configuration. This flight, with boilerplate 13 payload, should confirm the aerodynamic and structural designs of the Apollo spacecraft. The primary mission objectives of this flight are listed below:

a) Launch Vehicle Qualification for:

1. Structures
2. Propulsion
3. Guidance (ST-124 stabilized inertial platform)

b) Demonstrate the physical compatibility of launch vehicle and spacecraft under preflight and flight conditions.

c) Demonstrate the structural integrity of the Launch Escape System under flight loading conditions.

d) Demonstrate satisfactory launch escape tower jettison.

f) Demonstrate the compatibility of the R&D communications systems with the launch vehicle systems.

g) Determine the operational suitability of AMR tracking systems.

Achievement of the above objectives will result in the burned-out S-IV stage, instrument Unit, Adapter, SM, and CM (unseparated) attaining earth circular orbit of approximately 100 nautical miles.

SECTION III

3.0 MISSION PROFILE

The Saturn I spacecraft will be used for both manned and unmanned flights. The flights will be to qualify the vehicle and payload and to study the crew's use of the maneuvering, guidance and recovery systems. The Saturn I flight series is a portion of the logically programmed steps leading to the successful manned lunar landing flight and return.

Preflight and flight activities for SA-6 the second vehicle of the Saturn I-Block II series,are outlined as follows. See Figure 1.

3.1 Pre-AMR Activities

The spacecraft and the S-IV stage will be assembled and acceptance tested at the manufacturers' plant. The S-I stage will be assembled and tested at the Marshall Space Flight Center. Upon completion of the acceptance testings the spacecraft will be transported by air to AMR for field processing. The S-IV and S-I stages will undergo static firing at Sacremento, California and Huntsville, Alabama respectively, prior to shipment. The S-IV stage will then be transported by air and the S-I stage by barge to AMR.

3.2 AMR Activities

System checkout and radio frequency tests will be conducted on the stages and spacecraft prior to assembly of the Space Vehicle at AMR Complex 37B. After assembly, system tests and a simulated countdown will be conducted.

During the countdown, installation of ordnance and fueling will begin at T-2.75 hours and the gantry will be moved at T-2.50 hours. The countdown will proceed and at T-150 sec., the S-IV power will be transferred and the S-I and S-IV firing commands will be placed on auto sequence. The S-I power will be transferred at T-20 sec. and at T-0 ignition command will be given. At Lift-off, T + 3.42 sec., the hold down arms will release and the umbilicals will be disconnected.

3.3 Flight Operation

The initial S/C trajectory will be controlled by the S-I stage. S-I powered flight will continue until approximately T + 140 sec. S-I engine cut-off will occur and the S-IV ullage rockets will fire prior to S-I, S-IV stage separation at approximately T + 146 sec. At separation, control will be switched from S-I to S-IV and the S-I retro-rockets will ignite. Following ignition of S-I retro-rockets, tape recorder playback will occur and S-I cameras will be jettisoned.

At separation, (To)+ 1.5 sec., the S-IV engines will operate. The launch escape tower will be separated and jettisoned at (To)+ 11.5 sec. and the ullage rockets will be jettisoned at (To) + 20 sec. At approximately (To) + 460 sec., conditions for earth orbit are achieved and S-IV engines cut off.

Tracking motion picture coverage will exist for the launch phase, S-I staging, S-IV ignition, and escape tower separation.

Earth orbit of payload and other defined flight objectives will be accomplished by the successful operation of the SA-6 spacecraft. Configuration description of this Saturn I, Block II series vehicle is given in Section 4.0 of this report.

SECTION IV

4.0 HARDWARE CONFIGURATION

This vehicle consists primarily of the Spacecraft (BP-13), the S-I.U.-6 the S-IV-6 stage, and the S-I-6 stage. The spacecraft, manufactured by North American Aviation, will consist of the Launch Escape System. Command Module boilerplate (including Separation System Fairing), Service Module boilerplate, and an adapter and insert. The S-IV was manufactured by the Douglas Aircraft Company. The S-I and the I.U. were manufactured by MSFC. The SA-6 flight configuration is shown in Figures 2 and 3. The primary structures description, for both the Launch Vehicle and boilerplate 13 are described as follows:

4.1 S-I Booster Stage

The S-I stage is a LOX and RP-1 propelled stage comprized of eight Rocketdyne H-I engines with a thrust capacity of 188K lbs. each. The stage is approximately 80 ft. long and 21 ft. in diameter. It is the first stage of the two powered stages employed to inject the payload into earth orbit.

4.2 S-IV Booster Stage

The S-IV stage is a liquid oxygen and liquid hydrogen propelled unit, utilizing six RL10A3 Pratt and Whitney engines of 15,000 lbs. thrust each, for a total thrust of 90,000 lbs. This stage, approximately 18½ ft. in diameter and 42 ft. long is the second propulsive stage of the two powered stages employed to inject the payload into earth orbit.

4.3 Instrument Unit

The IU is a pressurized unit containing instrumentation and guidance systems. With a length of approximately 4 ft. and a diameter of 13 ft., it forms a connecting link between the payload and the S-IV stage.

4.4 Adapter Section (S/Ca)

The S/Ca is a semi-monocoque type aluminum structure and is attached to the insert and instrument unit with bolts. It contains an air-conditioning barrier as well as instrumentation sensors and associated cabling. Weight is 2100 pounds.

4.5 Service Module (S/M)

The boilerplate service module and insert are semi-monocoque type aluminum structures. The S/M is attached to the command module (C/M) by an inert or non-functioning separation system. The insert, bolted to the S/M, is bolted to the adapter section. An active umbilical system, instrumentation sensors, associated cabling and ballast are contained in the S/M. Also included are a dummy Reaction Control System (RCS), quadrant packages having the same size, weight, shape, location, and aerodynamic characteristics as live S/M RCS packages. Weight of this boilerplate is 7740 pounds.

4.6 Command Module (C/M)

The command module (C/M) is a boilerplate structure simulating the size, shape, weight, and C.G. of the Manned Spacecraft. It is a semi-monocoque type aluminum structure containing provisions for separation of the launch escape tower. The C/M will carry a partial environmental control system for C/M temperature control and a partial electrical power system (EPS) to furnish boilerplate power requirements. Also carried will be a partial Communications and Instrumentation System (C&I) which includes the signal conditioning package, "C" band transponder, data acquisition system, and telemetry antenna. Weight of this boilerplate is 8760 pounds.

4.7 Launch Escape System (LES)

The launch escape system (LES) configuration consists of the following:

a. Q-Ball. A dynamic pressure sensor for measuring the angle of attack for use in trajectory information.

b. Pitch Control Motor. This motor will be inert.

c. Launch Escape Motor. This motor will be inert.

d. Tower Jettison Motor. A solid propellant reaction motor which will develop 33,000 pounds of thrust for one second with burnout occurring at approximately 1.3 seconds.

e. Tower Structure. This structure is a welded tubular, titanium alloy, truncated rectangular structure which is operational configuration. The tower forms the intermediate structure between the C/M and the Launch Escape Motor and has a Pyrotechnic release mechanism for the tower to C/M separation system. Weight of this system is 6,600 pounds.

SECTION V

5.0 METHODOLOGY

This section defines the methods and techniques which will be utilized as management tools to summarize and analyze the Apollo Test Program in order that a determination of the test maturity can be made relevant to flight SA-6.

While this section of this report will be quite brief, it will be more detailed in subsequent reports as new techniques and methodologies are developed and utilized in the analysis of the Apollo Test Program. Promising techniques are currently under investigation. However, none of them are mature enough at this time to present in this type of report. These techniques will be orally and graphically illustrated to cognizant NASA APOH personnel prior to utilization or inclusion in any of the subsequent test maturity analysis reports.

The first of these techniques to be utilized is one in which strong consideration is given to mission phases, associated environments and test experience satisfying these conditions. Discussions on this technique will be conducted with cognizant NASA personnel in the very near future.

Other techniques are being considered that utilize information from the following general areas, since these areas have a primary impact on the maturity of any test program.

a. Environment vs mission phases.

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b. Test sequence and interrelationships.

c. Test durations and hardware quantities.

d. Hardware configurations.

e. Equivalent systems and/or equivalent missions.

f. Support, handling equipment and facilities.

g. Operations and procedures.

The methodology used in this current report is not new or unique. In fact the review consisted primarily of a survey of the existing test documentation by systems test engineers who then prepared comments relative to the impact on Flight SA-6.

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SECTION VI

6.0 ANALYSIS

6.1 General

The analysis that has been made was based upon the review of applicable general test plans, the first issue of the Apollo Qualification Test Summary Report, monthly and quarterly program and reliability progress reports and other pertinent documentation. No attempt was made to make a complete analysis of all factors which affect maturity of the SA-6/BP-13 flight. Rather, a few representative comments are made based upon problems which were discussed in some of the progress reports.

The launch vehicle will not be considered in this analysis except to emphasize that SA-6 is essentially identical to SA-5 and that the SA-5 test objectives were satisfied during the recent flight test. One difference which probably will exist is that the ST-124 stable platform will be employed for closed-loop guidance for the first time. The ST-124 has been flown as a passenger on previous flights including SA-5 and has been thoroughly instrumented to permit a judgment to be made of its capability to perform the guidance function. The next issue of this report will contain a more extensive analysis of the launch vehicle.

6.2 Specific Analyses

6.2.1 BP-13 Test Constraints

An examination of the diagram depicting the Apollo Spacecraft Qualification Test Program (see reference 1) reveals some interdependencies among boilerplates 3,6,12 and 19 with boilerplate 13. BP-3 provides constraints to BP-6 and BP-19, BP-19 provides constraints to BP-12 and BP-12 provides constraints to BP-13. Pad Abort PA-1 with BP-6 was completed 7 November 1963 and the test objectives were satisfied. Therefore, BP-3 provided the necessary information for BP-6 before BP-3 was destroyed in a recovery system test failure. It is not known whether BP-3 provided the necessary information to BP-19 and whether BP-19 provided the information to BP-12 with respect to BP-13 requirements. Little Joe II-2, with BP-12, should have been launched near the end of January 1963 but it has slipped. Two potential problems associated with BP-12 are known. First Little Joe II-2 may slip as a result of the test constraints imposed by BP-19 test status. It is known that drop test #7 of the BP-19 test program was successfully completed in December 1963 and this satisfied the constraints for BP-6. It is not known that BP-12 constraints have been satisfied. Second, the hardware to accomplish the eleven changes which were required to allievate the causes of the BP-3 test failure, and which must be incorporated into BP-12, may not be available in time to prevent a further slippage to the Little Joe II-2 flight. All of these factors have a bearing on the launch of SA-6/BP-13. It is known that SA-6/BP-13 has slipped but a new date is not available.

6.2.2 Tower Jettison Motor Vibration Tests

It was discovered that there was a 70° F temperature rise in the solid propellant during a vibration test on a tower jettison motor. Further testing on two additional motors yielded conflicting results. A temperature rise of 1° F per minute in the solid propellant was observed on one motor as it was subjected to a critical vibration frequency; there was no similar result on the second motor. It appears that this temperature rise with vibration is not clearly understood, but it is known that there is a relationship between motor performance and solid propellant temperature. Since SA-5 has been successfully launched, information on the vibration profile which can be anticipated for SA-6/BP-13 is available. A study should be made to determine whether the tower jettison motor is likely to encounter any critical frequency which would cause its propellant to experience a temperature rise under flight conditions. It appears that the testing on these two motors terminated the planned development test program, 1 December 1963. Consideration should be given to extending this test program to further investigate the vibration/temperature relationships.

6.2.3 <u>Pyrogen Unit for the Tower Jettison Motor</u>

There are two problems involving the pyrogen unit in the tower jettison motor. One is the production of high pressure spikes upon initiation by the hot wire initiator. Post test examination provided evidence of damage to the boron pellet basket. Thiokol is investigating the modification of the initiator to eliminate this pressure spike. The status of this investigation is not known. The October 1963 boilerplate 13 DEI-AP 63-71 establishes November 15, 1963 as the date for final initiator testing. The 1 December 1963 monthly progress report indicates that this testing has not been completed. There is an apparent slip, the extent of which is unknown.

Secondly, there was a problem with damage to the boron pellet basket under vibration testing. Redesign was accomplished at that time and the problem was apparently solved. However, in view of the pressure spike causing additional problems, it is recommended that a careful re-evaluation be given these problems prior to the launch of SA-6/BP-13.

6.2.4 <u>Q-Ball Failure</u>

The December 1963 Monthly Progress Report indicated that the Q-Ball which was allocated for BP-12 failed during vibration testing. The cause and extent of the failure is unknown. Since the Q-Ball is an important part of the SA-6/BP-13 instrumentation, an investigation should be conducted to determine the suitability of the unit for use in the flight.

6.2.5 <u>Possible Scheduling Conflicts</u>

The 3rd Quarter Reliability Report indicates that separation testing-escape tower from command module is scheduled to be conducted during the period from May 1963 to April 1964. Care must be employed to assure that all the necessary separation testing required for SA-6/BP-13 will be completed several weeks prior to the launch of that vehicle. It is known that an additional separation mode for tower jettison is being designed and testing for this mode has been included in the test program as scheduled above.

In the same report, vibration and acoustic noise tests have been planned for typical service module structural panel sections during the period from December 1962 through January 1964. Part of this testing is probably a constraint on BP-13 service module structure. Although the schedule does not appear to be too tight, if redesign should be found necessary, then hardware availability could become a problem for SA-6/BP-13. It should be ascertained that no delay of this nature seems eminent.

6.2.6 <u>MILA Testing</u>

BP-13 will provide the first opportunity to utilize the equipment and procedures for spacecraft testing at MILA. It is recommended that a review be made to assure that testing will be conducted smoothly, as required, and without human error to the maximum extent possible. An example of the kind of error that can be avoided by having good procedure requirements is the block that was inadvertantly left in a liquid oxygen line during the SA-5 countdown.

6.2.7 Equipment Qualification Status List

When complete and current hardware qualification status become available, the list will become meaningful. Refer to Figure 4. The status of the hardware will be analyzed to determine whether or not this status will have an effect upon the ability of the vehicle to achieve the mission objectives. If there are items which have not been completely qualified, a determination will be made relative to the impact of this status upon the flight. The status of the hardware is not available at this time. Consequently, many hardware items which appear in the "Qualification Tests Incomplete" column might, in fact, now be completely qualified. It is hoped that information will become available so that the hardware status will be known and so that a meaningful analysis can be presented in the next issue of this report.

6.2.8 Ground Support Equipment

There was a problem with the GSE which was used in testing the S-IV All Systems Vehicle at a Douglas facility on the West Coast which caused the vehicle to be destroyed. Presumably, identical, or similar, GSE will be utilized at MILA for S-IV Stage Checkout. It is recommended that a thorough analysis be made to determine the cause of failure and that appropriate remedial action be taken at MILA prior to the SA-6 checkout.

SECTION VII

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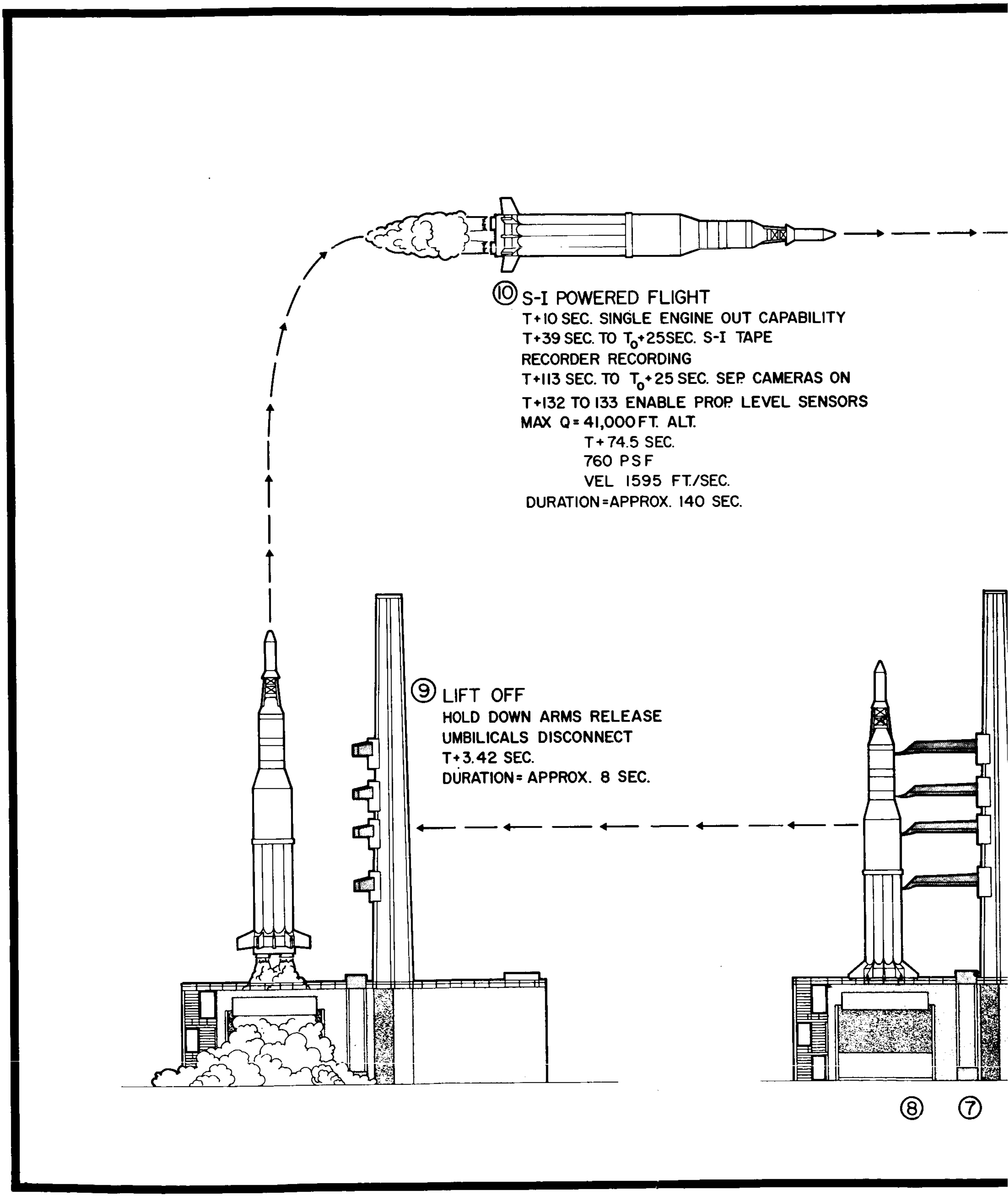
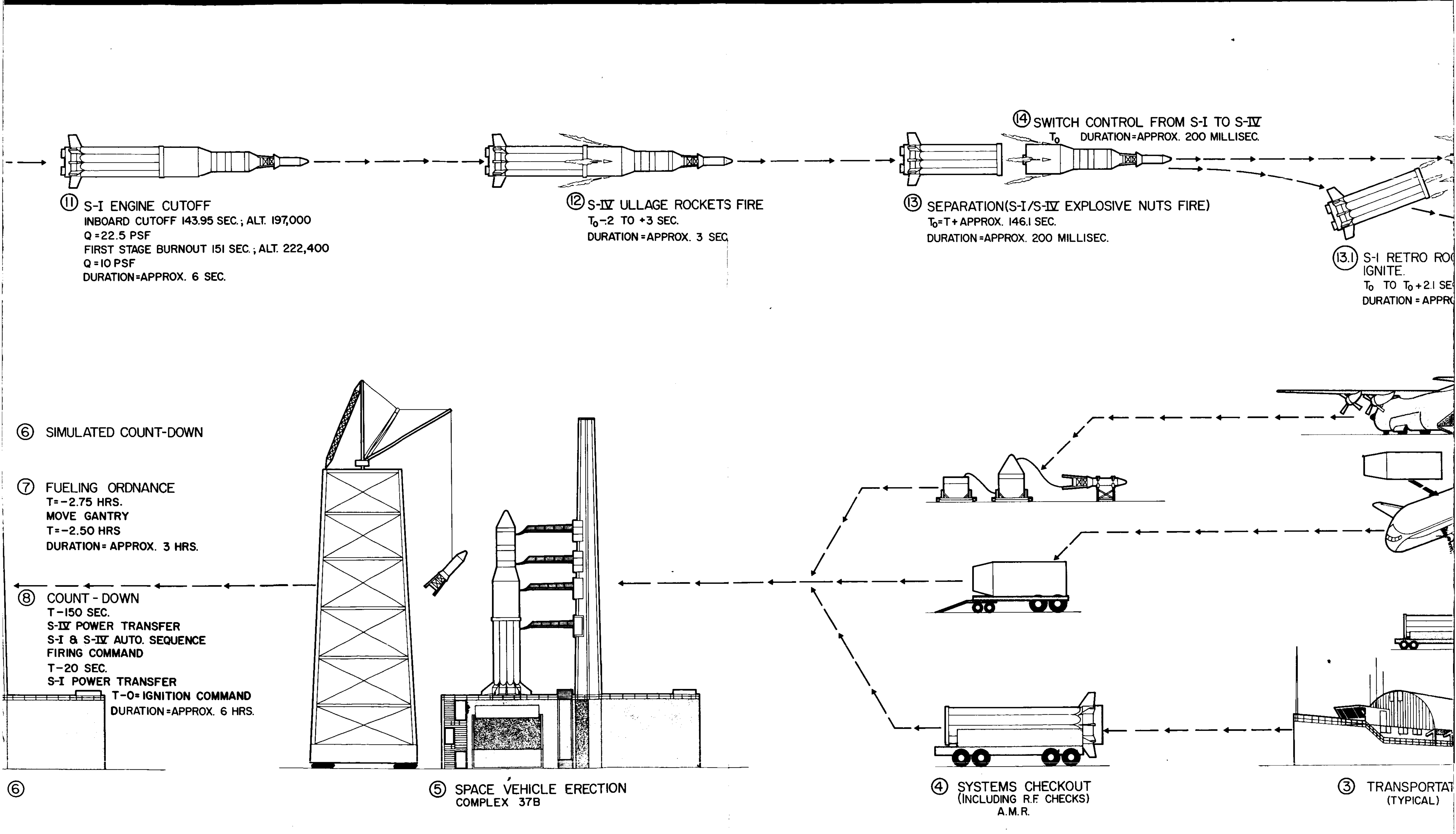
SECTION VIII

DRAWINGS


10 S-I POWERED FLIGHT
T+10 SEC. SINGLE ENGINE OUT CAPABILITY
T+39 SEC. TO T_0+25SEC. S-I TAPE
RECORDER RECORDING
T+113 SEC. TO T_0+25 SEC. SEP. CAMERAS ON
T+132 TO 133 ENABLE PROP. LEVEL SENSORS
MAX Q = 41,000 FT. ALT.
T+74.5 SEC.
760 PSF
VEL 1595 FT./SEC.
DURATION=APPROX. 140 SEC.
9 LIFT OFF
HOLD DOWN ARMS RELEASE
UMBILICALS DISCONNECT
T+3.42 SEC.
DURATION= APPROX. 8 SEC.
8
7



(11) S-I ENGINE CUTOFF
INBOARD CUTOFF 143.95 SEC.; ALT. 197,000
Q = 22.5 PSF
FIRST STAGE BURNOUT 151 SEC.; ALT. 222,400
Q = 10 PSF
DURATION = APPROX. 6 SEC.
(12) S-IV ULLAGE ROCKETS FIRE
T_0-2 TO +3 SEC.
DURATION = APPROX. 3 SEC.
(14) SWITCH CONTROL FROM S-I TO S-IV
T_0
DURATION = APPROX. 200 MILLISEC.
(13) SEPARATION (S-I/S-IV EXPLOSIVE NUTS FIRE)
T_0=T + APPROX. 146.1 SEC.
DURATION = APPROX. 200 MILLISEC.
(13.1) S-I RETRO RO
IGNITE.
T_0 TO T_0 + 2.1 SE
DURATION = APPR
(6) SIMULATED COUNT-DOWN
(7) FUELING ORDNANCE
T = -2.75 HRS.
MOVE GANTRY
T = -2.50 HRS
DURATION = APPROX. 3 HRS.
(8) COUNT - DOWN
T -150 SEC.
S-IV POWER TRANSFER
S-I & S-IV AUTO. SEQUENCE
FIRING COMMAND
T -20 SEC.
S-I POWER TRANSFER
T-0 = IGNITION COMMAND
DURATION = APPROX. 6 HRS.
(6)
(5) SPACE VEHICLE ERECTION
COMPLEX 37B
(4) SYSTEMS CHECKOUT
(INCLUDING R.F. CHECKS)
A.M.R.
(3) TRANSPORTAT
(TYPICAL)

2

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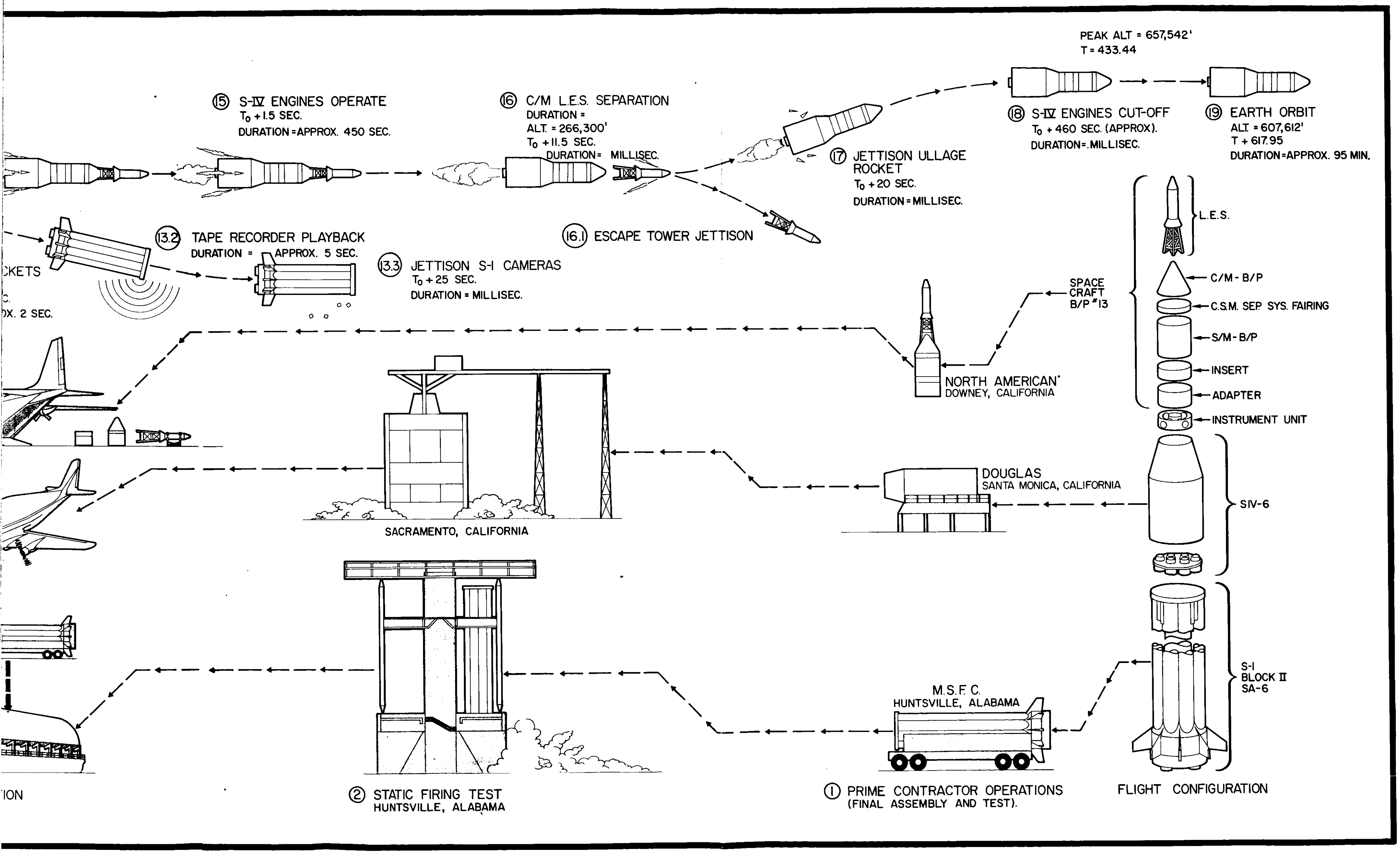

FIGURE I

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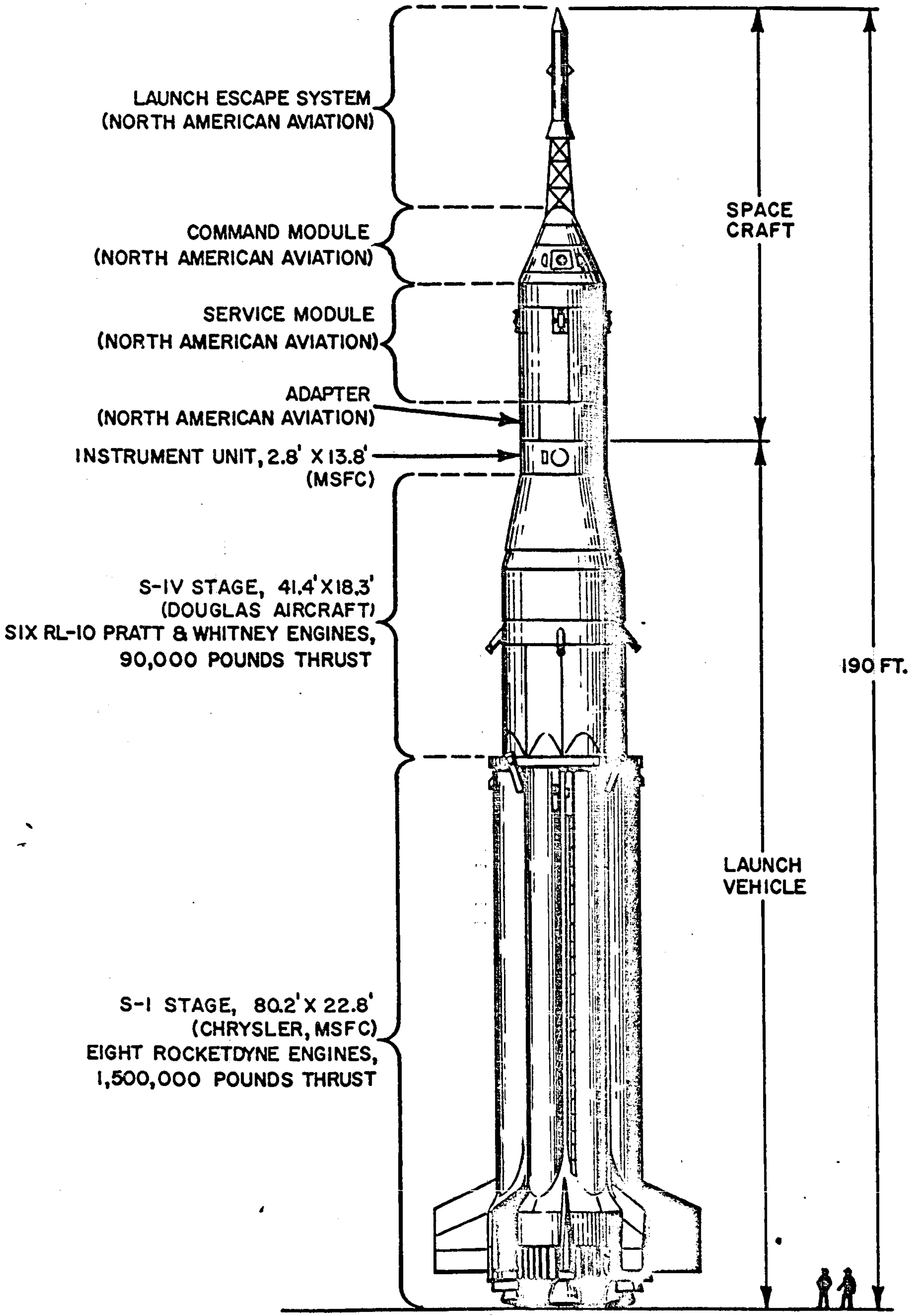

SATURN I - BLOCK II

FIGURE 2

[redacted]

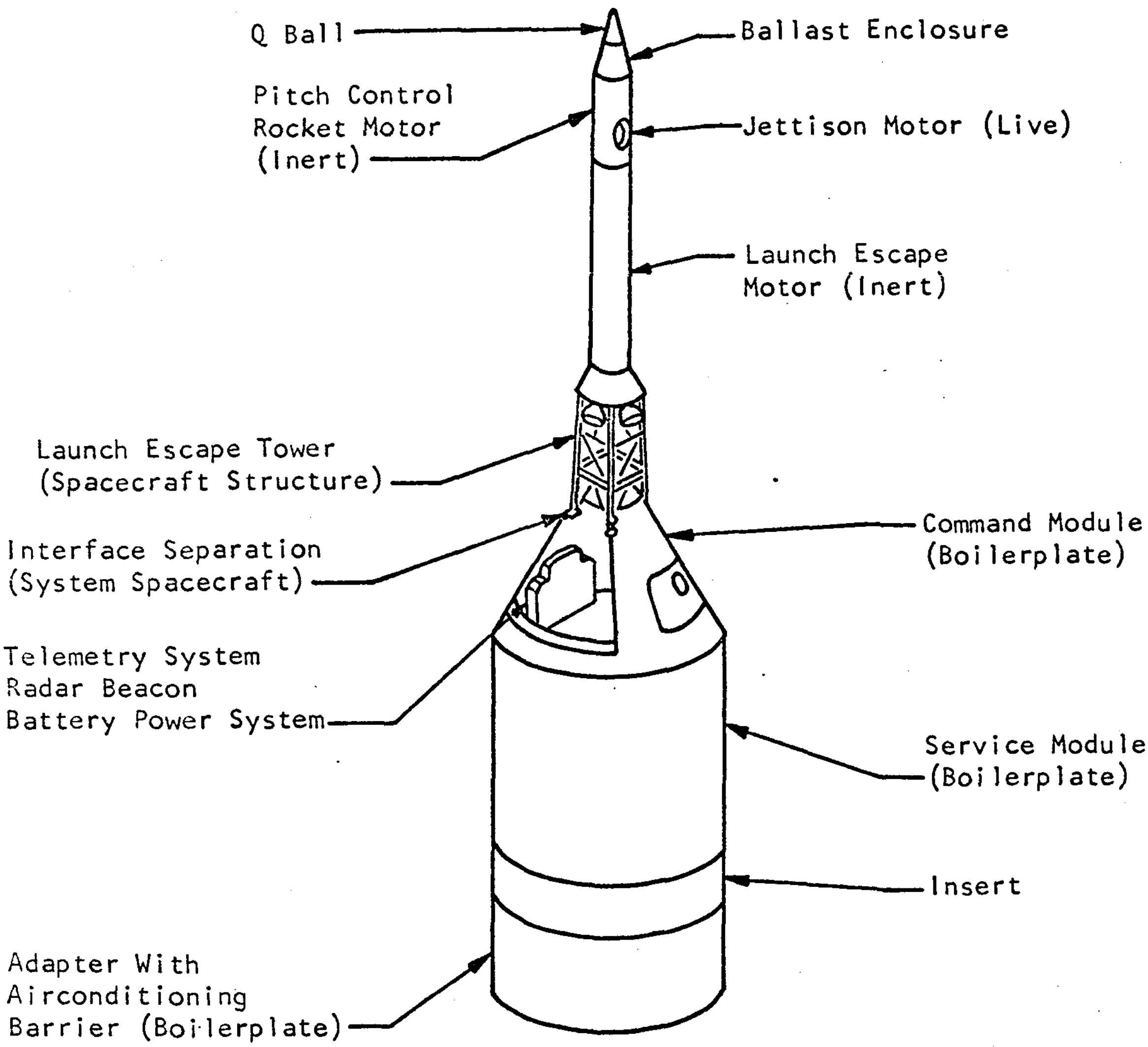

FIGURE 3

BOILERPLATE 13 CONFIGURATION

HARDWARE QUALIFICATION STATUS TREE

SA-6 BP-13 Launch Environment

- **Qualified Items**
  - Thermal Protection System
    - Forward Compartment Insulation
    - Aft. Heat Shield
- **Qualification Program Incomplete**
  - Electrical Power System
    - Batteries
    - Control Box
    - Junction Box
  - ** Launch Escape System
    - Tower Jettison Motor
    - Launch Escape Motor
    - Pitch Control Motor
    - Tower Structure
    - Launch Escape Sequencer
    - Escape Tower Separation Mechanism
  - Environmental Control System
    - *Storage Tank
    - *Pump
    - Cold Plate
    - *Heat Exchanger
    - *Fan
    - *Thermal Control Valves
    - *Quick Disconnect Valves
  - Aft. Heat Shield
  - Mechanical Devices
    - SM/Adapter Separation System.
- **R & D Items** **
  - Communi cation and Instrumentation Systems
    - Data Acquisition Sub System
    - Signal Conditioner
    - C-Band Transponder
  - Launch Escape Motor
  - Pitch Control Motor
- **Passenger and Inert Items**
  - Reaction Control System
    - Motors
  - Launch Escape Motor
  - Pitch Control Motor

** Constraints for BP-13 is successful Qualification of these systems on boilerplate abort tests conducted at WSMR

* No qualification program indicated SID 62-109-3 page 3-9.

Test Objectives

1. Demonstrate the physical compatibility of launch vehicle and spacecraft under pre-flight conditions.
2. Determine the launch and exit environmental parameters to verify design criteria.
3. Demonstrate the structural integrity of the Launch Escape System under flight loading conditions.
4. Demonstrate satisfactory Launch Escape Tower jettison.
5. Demonstrate the compatibility of the R&D communications and instrumentation system with the launch vehicle systems.

FIGURE 4